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# Peer-mediation of the adoption of efficient software interaction methods: A model based on priming

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ABSTRACT

Our peers are an important source from which we glean new information or are reminded of old information that influences our behavior (Bandura, Ross, & Ross, 1961; Osman, 2008; Rieman, 1996). One important domain in which this phenomenon functions is the adoption of efficient means of accomplishing our work (Peres, Tamborello, Fleetwood, Chung, & Paige-Smith, 2004). Using a novel peer mediation paradigm, we performed an empirical study of efficient method adoption in a software usage task and observed a causal effect of peer behavior modeling. Our computational cognitive model explains the peer modeling effect in terms of priming the memory of the efficient method. We conclude that behavior changes do result from peer interactions that prime memories for the targeted behaviors.



## 1. Introduction

Developers of modern computer software packages, such as Microsoft Word®, typically employ complex user interfaces to present to the users the multiple methods available for issuing commands such as "make text bold". Although these systems are complex, past research has found strong evidence that most people learn software almost exclusively by exploring the interface on their own (Lane, Napier, Peres, & Sándor, 2005; Peres, Fleetwood, Yang, Tamborello, & Smith, 2005; Rieman, 1996) and this method of learning does not typically expose the user to all the possible functions or features available in the software. Thus users typically learn a small portion of the functions available in the software and usually only one method for performing a task even if others are available (Lane et al., 2005; Rieman, 1996).

The method adopted is usually the one that is most available on the user interface. Furthermore, once this most available method has been well learned users typically do not adopt new techniques (Carroll & Rosson, 1987). Unfortunately, the most available method learned may be inefficient even with software people use for a substantial portion of their workday (Lane et al., 2005; Peres et al., 2005). An extreme example of this is the architect described by Bhavnani and John (Bhavnani & John, 1998) who would quit and relaunch the entire program when he wanted to close one file and open another. Adopting inefficient techniques is problematic because their use decreases productivity relative to the use of efficient techniques.

Although the problem is not new (Carroll & Rosson, 1987), reliable predictors of advancement to expert levels of performance with software remain elusive. Factors that intuition would suggest are relevant (e.g., age of the user, time on task, etc.) do not predict users' leaving behind slow methods in favor of faster ones (Bhavnani & John, 1998; Bhavnani, Reif, & John, 2001; Carroll, 1997; Chadwick-Dias, Tedesco, & Tullis, 2004; Charman & Howes, 2003; Fu & Gray, 2004; Rieman, 1996; Tamborello, Peres, & Fleetwood, 2006).

For those people who do adopt efficient techniques, they must first acquire knowledge of the new technique and then select this technique instead of their well-learned preferred technique. The primary focus of past research has been on whether and how people choose to learn new techniques. Carroll and Rosson (1987) famously identified the "paradox of the active user," i.e., the notion that people generally do not want to stop their work to learn new more efficient techniques even though it may ultimately be beneficial. In this paradox, there is an implication that users weigh the benefits of acquiring (i.e., learning) new methods against the costs of taking time from their work.

(Fu & Gray, 2004) attempted to explain this paradox by suggesting that people are cognitive misers by nature, so they tend to use methods and strategies that have cues and offer immediate feedback on users' progress through the problem space and also apply in multiple situations. For instance, previous work found it to be

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faster to use the Keyboard to Issue Commands (KICs) than to use mouse-operated menus or icon toolbars (Lane et al., 2005). Yet the same study also found that people tended to use slower methods for issuing equivalent commands. In the slower methods i.e., menus and icon toolbars on the Graphical User Interface (GUI), there is a general procedure (move the mouse to search for the command) and interaction (the computer shows the available commands and users see the mouse cursor on the command as they issue it). On the other hand KICs tend to be specific, do not offer incremental feedback, and their cues may not be immediately available. In this case, Fu and Gray argue, people may rely upon information provided by the GUI for cues on how to input a command rather than relying on their memory.

Peers are often a critical fallback resource for users (Rieman, 1996). Rieman found that when a user encountered a problem there was somebody immediately available who already knew the answer and asking that person was the quickest way to get to the answer. Critically, human helpers, as opposed to documentation, were sensitive to the level of detail needed by the user and could respond with overview- or detail-level information as context determined which was appropriate. Another important possibility is that proactive, interactive peers may introduce knowledge of new, more efficient methods on their own initiative. Furthermore, Osman (Osman, 2008) found that users are good at learning by modeled example, including when there may be multiple applicable methods. Osman's and Rieman's work suggests that in some circumstances users may be able to learn methods that perhaps only have indirect relevance to their goal, such as alternative methods that are more efficient, if they are modeled and come at an appropriate time during task execution.

Other evidence suggests that people who associate with knowledgeable peers also tend to be more knowledgeable about the software that they use (Chadwick-Dias et al., 2004). Chadwick-Dias et al. (2004) found that older Internet users who had someone in their home who also used the Internet knew more about using the Internet than those who did not, suggesting that this difference was due to transference of knowledge between Internet users within a household. In fact, Chadwick-Dias et al. (2004) reported that performance was more related to the opportunities people had for collaboration than the number of hours or years of experience they had.

The findings of the influence of peers on people's knowledge is not remarkably different from social learning theories developed from studies such as Bandura's imitative aggression studies (Bandura et al., 1961). These researchers have for a long time stated that humans seem to be hard-wired to learn from peer modeling of behaviors. Indeed, Stroebe, Mensink, Aarts, Schut, & Kruglanski, (2008) and Stroebe, van Koningsbruggen, Papies, & Aarts (2013) examined behavior change in a dieting setting. They found that dieters who spent more time in environments with stronger pro-change behavior and weight control cues tended to lose more weight relative to dieters who spent more time in environments with more contrary, anti-change behavior, and food enjoyment cues.

Stroebe et al.'s findings suggest that working with or being near peers engaging in a particular behavior (e.g., dieting or using efficient techniques) not only gives users the opportunity to learn the techniques but moreover primes users to actually use these efficient techniques. Specifically, observing others use efficient techniques may create a bias for using that technique over another. Since the 1970s, researchers have found that priming is a reliable and powerful method of leveraging the implicit memory to influence behaviors and responses (Laberge, Van Gelder, & Yellott, 1970; Posner & Snyder, 1975; Rosenbaum & Kornblum, 1982). Priming could be the cognitive mechanism associated with people adopting behaviors – behaviors they know about and do not use—after they have observed someone using them.

In summary, current research has found that people tend to not adopt new techniques even when they are more efficient unless they have peers who use those more efficient techniques. Although the findings from these studies are significant and meaningful they are also correlational – therefore they cannot speak to whether there is a causal relation between observing others' use of efficient techniques and the adoption of those techniques. We submit that peers may serve an important role as primes for retrieval of the efficient methods, and that priming acts as an important factor in behavior change for software users. Specifically, that observing peers use efficient techniques is a causal agent associated with the adoption of these techniques.

We intend to define a quantitative account of social learning and to do so for a common and economically-important behavior, using efficient methods of interacting with office productivity software. First we show a causal relationship between observing others and the adoption of KICs through experimental manipulation. Then we construct a mechanistic, quantitative account of the influence of peer observation on the adoption of efficient software interaction techniques. The model is important for elucidating the cognitive mechanisms that underly the social learning effect, that peers prime one behavior in a competitive memory retrieval process.

## 2. A KLM model of interaction with software

Before continuing with an investigation of the impact of observing peers on the adoption of an efficient technique, we had to confirm that the technique was more efficient in all circumstances. Specifically, although Lane et al. (2005) found that using KICs was a more efficient way of interacting with software, they collected data on only four commands, i.e., Copy, Paste, Open, and Save and three of these commands (Copy, Paste and Save) require use of the left hand only to issue the command. However, to implement KICs from the right side of the keyboard (for the Open command), users have to remove their right hand from the mouse and use it to press the appropriate letter key and then return their right hand to the mouse. This additional hand movement may mean that using KIC is only efficient for those commands that have keys on the left side of the keyboard because of the extra movement time required for moving the right hand from the mouse to the keyboard. Because Lane et al. collapsed their findings across the four commands, it could be that there was a difference between the commands on the two sides regarding efficiency thought it was not apparent statistically. To determine whether KIC is indeed more efficient relative to GUI methods for commands issued from both the left and the right side of the keyboard, we created a model of these times using a Keystroke-Level Model (KLM) (Card, Moran, & Newell, 1983; Kieras, Meyer, & Ballas, 2001). Although the space is not available here to give all the details of the KLM model, in summary the model consisted of someone issuing a command that required the left hand to use KIC (Bold) and a command that required the right hand to use KIC (Underline). We modeled the time it would take to issue both commands when the person started with the left hand on the keyboard and the right hand on the mouse, as well as when they started with both hands on the keyboard.

### 2.1. Results and discussion

The KLM estimates (Fig. 1) indicate that using KICs to implement commands is always faster than using the icon technique. Surprisingly, even for those commands requiring the right hand to issue the KIC, the time it took when the right hand had to be moved from the mouse (i.e., to issue the underline command with

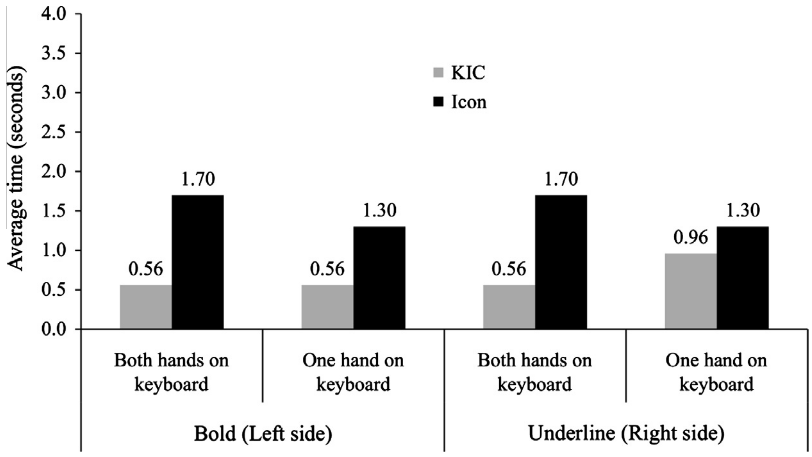


**Fig. 1.** KLM execution times for bold and underline commands. The bold command used the B key on the left side of the keyboard while the underline command used the U key from the right side of the keyboard. Two hand position scenarios were run for each command: "Start with both hands on the keyboard" and "start with the left hand on the keyboard and the right hand on the mouse." These two hand position scenarios were crossed with two interaction methods, KIC and icon toolbar. Results indicate that KIC takes less time than Icon in all scenarios.

Control + U) was only 0.4 s longer than when the right hand did not need to be moved. Additionally, although KICs were faster than the icon for issuing the underline command when the right hand was already on the mouse, this difference was only 0.34 s compared to a difference of approximately 1 s for the other conditions.

## 3. Experimental manipulation of peer-mediated behavior change

To empirically test whether there is a causal relationship between observing others' use of efficient techniques and the adoption of those techniques, we devised a novel paradigm mimicking a small collaborative office environment. Since we wanted to study software interaction method selection in the context of peer interaction we needed a relatively unconstrained task—by traditional cognitive psychology laboratory study standards—that would leave users free to use any of several methods to accomplish certain goals. This strategy gave us both the ability to study our chosen subject and lent ecological validity to our study. This is essentially the "microworlds" approach advocated by Brehmer and Dörner (Brehmer & Dörner, 1993). They argued that the result is a carefully controlled environment for observing the human as an interactive component of a larger system where it is possible to observe how the system's behavior affects strategic choice and behavior of the subject. This changes the level of observation, description, and analysis from that of traditional psychology laboratory studies to something much more akin to what occurs in human work environments.

### *3.1. Method*

#### *3.1.1. Participants*

Participants for this study were recruited through the Psychology program participant pool at University of Houston-Clear Lake (UHCL) as well as through announcements posted on campus at UHCL. There were 46 females and 23 males who participated in the study and their age ranged from 17 to 59 years with an average age of 30.38 (standard deviation 9.5) and this is representative of the UHCL student population. Each participant received either $30 or course credit for participating. Confederates (research assistants who were also students at UHCL) were used for the implementation of the independent variable.

#### *3.1.2. Design*

The dependent variable in this study was the participants' change in their use of efficient techniques from the first phase to the third phase (described in more detail below). There were four predictors of efficiency change explored in this study: efficiency observed, weighting of the costs of using KICs, weighting of the benefits of using KICs, and the participants' score on a test of their knowledge of Microsoft Word. We randomly assigned participants to one of three levels of the between-subjects variable, efficiency observed: Observing efficient techniques performed by a confederate ("efficient", $N = 29$), observing inefficient techniques performed by a confederate ("inefficient", $N = 27$), and observing a usability study ("comparison", $N = 14$).

There were three phases to the study and the efficiency variable was manipulated during the second phase. During the second phase the inefficient group observed a confederate using primarily icons to issue the commands and the efficient group observed a confederate using primarily KICs to issue commands. The comparison group observed the confederate performing tasks that were part of a usability study on a prototype of a departmental website.

#### *3.1.3. Materials*

All the data collection took place in the usability laboratory at the University of Houston-Clear Lake. The laboratory consists of a small observation room with direct access (through a doorway) to a control room. All participants used a PC running Windows XP equipped with a 17" monitor, Internet Explorer 6, and Word 2002. Researchers used Techsmith Morae software to observe the users' and confederates' software interactions remotely and encode them in a log file. These software interactions, including the number of times the participant used efficient or inefficient techniques, were recorded through camera observations, keystroke recordings, and experimenter observations, which were encoded and tabulated by the experimenter. During the three phases, participants or confederates performed 15 tasks using Microsoft Word. These instructions were printed and included a list of fairly simple text editing tasks to perform. For example, in one task participants were told to find the title "Experience is not Generality" in the Microsoft Word file and make that text bold.

#### *3.1.4. Procedure*

The first fifty-six participants were randomly assigned to one of the two experimental conditions – observing efficient or inefficient behavior. A preliminary analysis of the results, as will be seen, suggested we needed a baseline measure from a group who would not receive priming for the efficient or inefficient behaviors. The comparison group observed the confederate perform tasks associated with navigating a website using Internet Explorer. As is typical with most website navigation, this condition required the confederates to use the mouse to perform the tasks. The fundamental difference between this condition and the inefficient condition is that when navigating a website, there is not a readily available (or well known) alternative to using the mouse for navigation as there is for issuing commands in Microsoft Word®. Thus, there is no opportunity for participants to engage in an evaluation of using the mouse over some other method of performing the tasks. All other aspects of the comparisons group procedures (described below) were identical to the efficient and inefficient groups.

For all conditions, the participant was initially instructed to go into the observation room and the confederate was instructed to remain in the control room. At this point, the researcher instructed both the confederate and the participant that they would complete three different tasks, the first task they would complete separately and the second and third task they would complete together. During the first phase, the pre-intervention, with the confederate in the other room, participants performed the editing tasks in a Microsoft Word document. This phase provided baseline information regarding how frequently that participant used KICs for editing Microsoft Word documents.

Upon completion of the first task list, the researcher asked the confederate to join the participant in the participant's room for the second phase. The participant and confederate were told that during this next phase one of them would read instructions from a task list while the other participant (the confederate) completed the next phase. The intervention was presented during this second phase of the study. In the efficient condition, the confederate completed editing tasks similar to those in Phase 1 and primarily used KICs to issue the commands. In the inefficient condition, the confederate completed the same list of editing tasks as in the efficient condition but primarily used the icon method of issuing the commands. Participants saw on average 54 (standard error 1.3) commands issued during this phase for both the efficient and inefficient conditions.

In the comparison condition the confederate used the mouse to complete tasks for a website usability study. The comparison was designed so that it had all the demand characteristics of the efficient and inefficient conditions. Specifically, the participant read a list of tasks to the confederate and watched the confederate perform those tasks using Microsoft Internet Explorer in Windows XP. The primary difference between the comparison condition and the two experimental conditions was that for comparison condition, the participant observed neither efficient nor inefficient techniques to issue commands in Microsoft Word. Thus, for participants in the comparison condition, any difference between their efficiency in Phase 1 and Phase 3 was due to exposure to the task rather than exposure to the confederate's methods or practice effects and thus reflects the amount of change that would have happen regardless of what the participant observed during the second phase.

The third phase of the study, post-intervention, was identical for all three conditions and the confederate was told to read the instructions to the participants while the participants completed a task list very similar to those in the first phase. In both pre- and post-intervention phases, for each task, participants had at least one opportunity to issue a command using either the keyboard or another method. However, participants were not constrained in the number of commands they could issue to accomplish a task. Therefore there were not a specific number of commands issued in each phase by each participant.

After the completion of the post-intervention phase, the confederate and participant were told that they needed to be in separate rooms to complete the final surveys. Upon completion of the surveys, the participant was debriefed regarding the nature of the study. After the study was completed, none of the participants indicated awareness that the person they had worked with was a confederate.

#### 3.1.5. Measures

*3.1.5.1. Change in efficiency.* To measure the participants' change in their use of efficient techniques, we first calculated the percentage of times they used a KIC for each command (i.e., cut, copy, paste, bold, italicize, underline, and find) for the first phase and then averaged these percentages. For instance, if a participant used the find command 10 times in Phase 1, half of these times with the efficient method to issue this command, that participant would have a 50% efficiency for find for Phase 1. The same calculation would then be done for each of the other seven commands. We then would average the efficiency of the eight commands and that value would be this participant's efficiency for Phase 1. We calculated this same variable for the third phase of the study and subtracted the average percentage of the first phase from the third phase. This gave their change in KIC usage from the first phase to the third phase.

*3.1.5.2. Efficiency observed.* Analyses were conducted using a categorical measure of the independent variable (efficiency observed) with three levels (efficient, inefficient, and comparison). The confederates were not 100% consistent with their use of the efficient or inefficient condition methods for issuing commands. In retrospect, this is not surprising given that the procedure of issuing commands often becomes automatic and behaviors that have developed to automaticity are very difficult to change (Anderson, 2007; Cooper & Shallice, 2006). Although the confederates were not 100% accurate in implementing the intervention, there was a significant difference between the Efficient and Inefficient group in the number of times KIC was used, $t(54) = 84.7$, $p < 0.001$, thus the categorical variable of efficiency observed is valid.

*3.1.5.3. Costs and Benefits of KIC.* To measure the importance participants gave the costs and benefits of using KICs, each participant answered 30 questions asking them to rate the importance of a statement in their consideration of using the efficient technique. For example, one question regarding the costs of KIC was, "Learning keyboard-issued commands would take a long time." Participants responded using a 5-point scale with 1 being "not at all important" and 5 being "very important." We calculated participants' average responses on those items asking participants to weigh the costs and on those items asking participants to weigh the benefits.

*3.1.5.4. Knowledge of microsoft word.* To identify participants' knowledge level with Microsoft Word, they completed a 20 item multiple-choice test on functions associated with Microsoft Word. This test was developed from an online Microsoft Test (Microsoft, Inc., n.d.).

*3.1.5.5. Computer use.* To investigate the impacts that computer/software use may have on the likelihood of someone increasing their KIC usage, participants provided information on the years they had used a personal computer (PC), and the number of hours per week they used a PC.

#### 3.1.6. Results

Table 1 provides the mean, standard deviation, and standard error for the variables associated with the participants' computer

**Table 1**
Means and standard errors for the possible predictor variables: Age, Years with a PC, Hours per week on a PC, Knowledge of Microsoft Word, Weightings of the Costs and Benefits of using KICs, number of commands issued pre and post task, and Use of KIC pre and post task (*N* = 69).

| Variable | Mean | St. dev. | Std. error |
|---|---|---|---|
| Age | 30.4 | 9.5 | 1.15 |
| Years with a PC | 10.9 | 5.2 | 0.62 |
| Hours per week on a PC | 23.7 | 18.26 | 2.20 |
| Knowledge of Microsoft Word | 10.2 | 3.8 | 0.45 |
| Costs of using KICs | 2.66 | 0.68 | 0.08 |
| Benefits of KICs | 3.12 | 0.66 | 0.08 |
| Number of commands issued Phase 1 | 43.3 | 14.5 | 1.7 |
| Percent KICs usage at Phase 1 | 33% | 28% | 3% |
| Number of commands issued Phase 3 | 55.2 | 17.2 | 2.0 |
| Percent KICs usage at Phase 3 | 38% | 29% | 03% |
| Percent Right-handed | 90% | | |

usage. As seen in Table 1, participants had used a PC for an average of 10.9 years and they currently used the PC 23.7 h per week. The average number of correct answers on the test of their knowledge of Microsoft Word was 10.9 (out of a possible 20). The average ratings of the importance of the costs and benefits of using KIC were 2.66 and 3.12 respectively on a 5-point Likert scale (1-"Not important" and 5-"Extremely Important"). Regarding their overall usage of KIC, on average participants used KIC 33% of the time during the pre-intervention task and 38% of the time during the post-intervention task. The average age was 30.4 and 90% of the participants were right handed. Of the 10% who were left handed, there were 3 in the efficient group, 3 in the Inefficient group, and none in the comparison group. Participants issued an average of 43.3 commands during the first phase and 55.2 commands during the third.

The distributions for hours per week on a PC, and percent KIC usages at Phases 1 and 3 were skewed (skews equal 0.93, 1.12, and 0.85 respectively). To correct for this, a $\log_{10}$ transformation of these three variables was done. These transformations resulted in respective skewness of −0.63, 0.86, and 0.60. The results when the analyses were done with the transformed variables were not different in direction, significance level, or effect size. Thus for ease of interpretation, all analyses were done with the non-transformed variables.

*3.1.6.1. Predicting initial use of efficient techniques.* Several sets of analyses were conducted on the data collected. The first analyses were designed to identify the variables that were associated with participants' typical usage of KICs. This pre-intervention phase was considered an approximation of what the participants would likely do during their normal usage of Microsoft Word.

Table 2 shows a correlation matrix for the variables associated with computer use and Efficiency. The variables related to participants' initial usage of KICs (or efficiency during pre-intervention) were their Knowledge of Word ($r = 0.242$, $p = 0.046$), their weightings of the importance of the Costs and Benefits of using KICs ($r = -0.446$, $p < .001$ and $r = 0.402$, $p = 0.001$ respectively). These results also show that none of these variables were related to how much the participants changed their use of KICs from the pre-intervention to the post-intervention. Not surprisingly, Knowledge of Word was also related to the years someone had used a PC ($r = 0.381$, $p = 0.001$) and the Hours per week someone uses a PC ($r = 0.377$, $p = 0.001$).

To examine how these variables individually contributed to the variability in the KIC usage for pre-intervention, a stepwise multiple regression was conducted with the KIC usage on the pre-intervention task as the dependent variable and their knowledge of Word, weightings of the costs, and weightings of the benefits were the independent variables. The model explaining the most variability ($r^2 = 0.297$) contained the participants' weightings of the costs and benefits of using KIC. The coefficients are listed in Table 3, and show that the $\beta$ values for both costs and benefits are significant ($p = 0.001$ and $.004$ respectively). The coefficient for knowledge of Microsoft Word ($\beta = 0.043$, $p = 0.702$) was not significant, and thus was eliminated from the model.

*3.1.7. Examining the effect of the intervention*

*3.1.7.1. By group.* As mentioned previously, we conducted some preliminary analyses with the two experimental groups and found that regardless of group, there were participants who increased or decreased their use of KICs. Fig. 2 shows that efficiency increased in both the efficient and inefficient condition. Fig. 2 shows that there were also participants who increased their KIC usage in the comparison condition but the magnitude of the difference was much smaller for this group than the Efficient group. Also, there were fewer participants who decreased their use of KIC in the comparison group. The fact that participants in the comparison group increased their use of KIC – even though the only activity they observed was the confederate using the mouse – suggests that people increase their use of KIC when they are more familiar with a task. These results confirm that observing a confederate navigate a website created a valid comparison group given that very few people decreased their efficiency in the comparison group (2 out of 14). Specifically, if simply observing someone using the mouse to click on the interface influenced people's behaviors, we would expect to the comparison group to look more similar to the Inefficient group since in the Comparison group the confederate used the mouse exclusively to click on links on a website.

To statistically examine the effects of observing efficiency on participants' change in efficiency we conducted a one-way ANOVA with change in efficiency as the dependent variable and the categorical measure of efficiency observed (efficient, inefficient, or comparison) as the independent variable. Fig. 2 shows the difference between the three groups and the descriptive statistics for each group are in Table 4. The ANOVA was significant ($F(2, 66) = 3.135$, $p = 0.05$, $\eta^2 = .09$). A Tukey's post hoc analysis

**Table 2**
Correlations between the variables associated with participants' use of the PC, ratings of the importance of KICs, and their actual usage of KIC (*N* = 69).

| | Age | Years PC | Hours per week on PC | Knowledge | Costs | Benefits | Eff. change |
|---|---|---|---|---|---|---|---|
| Age | | | | | | | |
| Years PC | 0.098 | | | | | | |
| Hours per week on PC | −0.069 | 0.229 | | | | | |
| Knowledge | −0.095 | 0.381** | 0.377** | | | | |
| Costs | 0.223 | −0.037 | −0.186 | −.0351** | | | |
| Benefits | −0.008 | 0.145 | 0.236 | 0.226 | −0.218 | | |
| Eff. change | −0.056 | 0.142 | −0.072 | −0.066 | 0.072 | 0.069 | |
| Eff. pre-int. | −0.188 | 0.110 | 0.232 | 0.242* | −0.446** | 0.402** | −0.213 |

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

**Table 3**
Coefficients of variables from the stepwise regression predicting participants' efficiency during the pre-intervention task ($N = 69$).

| Variable | $\beta$ | $t$ | $p$ |
|---|---|---|---|
| Costs | −0.377 | −3.56 | 0.001 |
| Benefits | 0.320 | 3.02 | 0.004 |

$r^2 = 0.297$.

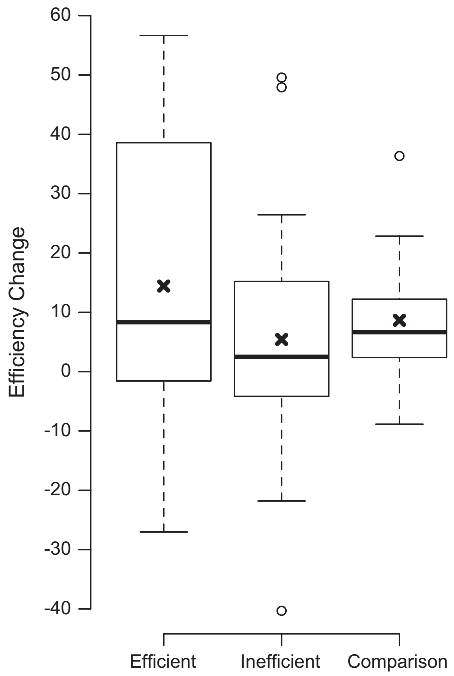


**Fig. 2.** Box plots represent the change in efficiency for the three groups – efficient, inefficient, and comparison groups. The "boxes" in the box plots represent the middle 50% of distribution, the bold line inside boxes represent the median, the "*x*" represents the mean, and the "whiskers" represent the minimum and maximum values of the distribution with outliers depicted as circles. The Efficient and Inefficient groups were different from each other ($p = 0.050$), but the comparison group was not different from either the efficient or Inefficient group ($p$'s = 0.817 and 0.368 respectively). $N = 69$.

**Table 4**
Descriptive statistics for the percent change in KIC for the efficient, inefficient, and comparison groups.

| | Limits of 95% confidence intervals | | | | |
|---|---|---|---|---|---|
| | N | Mean | SEM | Lower | Upper |
| Efficient | 28 | 0.094 | 0.029 | 0.035 | 0.153 |
| Inefficient | 28 | −0.009 | 0.029 | −0.068 | 0.050 |
| Comparison | 13 | 0.062 | 0.043 | 0.024 | 0.149 |

indicated that the efficient and inefficient groups were different from each other ($p = 0.04$) but neither the efficient nor inefficient groups were different from the comparison group ($p$'s = 0.82 and 0.37 respectively).

*3.1.7.2. General Observations of the Participants.* There were a few participants who saw the confederate use inefficient techniques who nevertheless increased their efficiency quite remarkably. One participant who increased her efficiency almost 60% whispered hints to the confederate regarding how she could use the keyboard to issue the commands and also told the confederate about how to use the find command for the task. This suggest that the participant knew about KICs at the beginning of the study but was simply not using them. Given her instructions to the confederate, it may be that her increased usage of KICs during the post-intervention phase of the study was meant to instruct the confederate on how to use them.

A participant in the inefficient condition used the efficient method to issue the cut, copy, and paste commands during the pre-intervention task but changed to the inefficient method after observing the confederate using this method. During the debriefing, she commented that she adopted the icon method because it seemed more efficient to her than the method she was using. Her comments indicate that she did not accurately perceive which method (KIC versus icon) was more efficient. Instead, she adopted the technique modeled to her (in this situation it was the less efficient icon method).

### 3.2. Discussion

There are two compelling stories regarding these results. When people observed efficient techniques they were more likely to use these techniques, and people's initial use of efficient techniques was associated with their weightings of the benefits and costs of using these techniques and not their knowledge or use of a software application. Although the amount of efficiency observed did not explain all the variability in the participants' efficiency change, the effect size ($\eta^2 = 0.09$) is a medium effect by Cohen's standards (Cohen, 1988).

Our finding that the likelihood someone would adopt efficient techniques could be manipulated through peer observation indicates that peer observation is a causal factor in the adoption of efficient techniques. It is important to note that if it were that people merely adopted the behavior they observed, we would expect the people in the comparison group to decrease their efficiency (i.e., increase their use of the method they observed-using the mouse). However, this was not the case. The participants in the comparison group increased their efficiency after Phase 2.

One explanation that has been frequently suggested to us for the relation between efficient behavior and knowing others who are efficient is the "Birds of a feather" phenomenon—specifically, efficient people may be more likely to be around (and thus observe) other efficient people. However, our findings show that this is not the case. Observing others who are efficient contributes to someone becoming more efficient. Further, the findings that years on a personal computer, or hours per day on a personal computer are not related to initial efficiency or efficiency change further supports the idea that simple exposure to computer systems is not the primary driver behind people's adoption of efficient techniques. Instead, that primary driver is observation of peers, and as our computational model demonstrates, the cognitive mechanism by which peer observation drives behavior change is priming of memories encoding each method.

## 4. A computational priming model for peer-mediated method selection

Stroebe and colleagues (Stroebe, Mensink, Aarts, Schut, & Kruglanski, 2008; Stroebe, van Koningsbruggen, Papies, & Aarts, 2013) studied behavior change within the milieu of chronic dieters struggling to lose weight. According to their goal conflict model, chronic dieters possess two conflicting goals: eating enjoyment and weight control. Though dieters may be motivated to control their weight, they often fail in food-rich environments because they experience powerful priming of the eating enjoyment goal. Assuming that observation of peers performing actions such as KICs primes an "efficient use of software" goal, this priming process could lead to behavior change in users. Further, Fu and Gray (Fu & Gray, 2004) suggested that users use GUI methods because those methods are primed by the GUI itself. We think it could be that, in the software use domain, priming may be useful for increasing availability of the user's memories for efficient techniques such as KICs and that it is by priming certain behaviors that peers have an impact on user behavior change. To demonstrate the sufficiency of priming as the active mechanism in peer-mediated behavior change, we created a computational model of behavior change premised on the priming of efficient behaviors by the observation of those behaviors in the actions of peers.

A computational cognitive model is a theory of human cognition that posits quantitative mechanisms for generating behavior. These models are usually instantiated in software as executable simulations that output, for example, time-stamped series of events such as button presses. We built our cognitive model within a framework known as a cognitive architecture, a general computational theory of human cognition. The architecture provides the elementary cognitive mechanisms, such as priming of declarative memory, while the model provides the task-specific knowledge and uses the architecture's mechanisms to explain task-specific behavior.

Cognitive modeling has several advantages as a methodology for evaluating hypotheses. Cognitive architectures such as ACT-R (Anderson & Lebiere, 1998; Anderson et al., 2004) force the method selection aspect of a model of human behavior to be explicitly accounted for. In doing so one can elucidate the complex interaction between learning, memory, and method selection on a particular task with a given interface. A cognitive model of a word processing task can make specific, explicit, quantitative and qualitative claims about the effects of experience and relative efficiency in method selection.

### 4.1. Method

We used ACT-R's activation-based system for retrieval of declarative memories to implement our theory of priming in a social learning environment. Retrieval activation is for our purposes determined by base-level activation, the strength of the memory due to frequency and recency of use. When the model attempts to retrieve a declarative memory, the memory with the highest activation is retrieved. All relevant declarative memory items (for our purposes, all software interaction method memories) compete for retrieval on the basis of activation and the declarative memory item with the highest activation is the one retrieved. The base-level activation of a memory rises and falls with retrieval and delay according to Eq. (1) where $t_j$ is the time since the $j$th practice of an item, $n$ is the number of presentations for chunk $i$, and $d$ is the decay parameter.

$$B_i = ln\left(\sum_{j=1}^{n} t_j^{-d}\right) \tag{1}$$

The model performed a simplified version of the word processing task in which it repeatedly performed one command, copy, and could do so either by clicking an icon or by pressing the "C" key. At the start of each trial the mouse cursor was set to a random location within a 1920- by 1200-pixel simulated computer display. The copy icon was a white rectangle 20 pixels high and 50 pixels wide, positioned 50 pixels below the top of the simulated display and 50 pixels right of the left edge of the simulated display. The task waited until the model either clicked the icon or pressed the "C" key to advance to the next trial. For each run the model performed 49 iterations of the copy command in the pre-intervention phase, 55 iterations of an abstracted peer observation of the KIC method during the intervention phase, and performed 60 iterations of the copy command in the post-intervention phase. These were the median numbers of individual tasks performed per subject in the efficient condition for each phase, respectively.

The two goals in our model, encoding the use of the icon and the use of a KIC to issue the copy command, competed for retrieval. The model began each run with base-level activations slightly higher for the icon method than for the KIC method, biasing its behavior toward performance of the icon method. Initial base-level activations of the two methods were important for both the Phase 1 efficiency and the amount of change during the intervention. Memories for both methods were assumed to be very stable, reflecting lifelong experience, and so the icon method had 10,000 retrieval references, the KIC method, 7500. This means that the icon method's memory had a higher base-level activation (4.535 activation units) than the KIC method's (4.341) at the start of each model run.

We simulated only the efficient condition of the experiment as that was of most interest and because the inefficient and comparison conditions showed no significant effect of intervention (Fig. 2). For the intervention phase, the software model performed an abstract observation of peer behavior by recording instances of having retrieved the KIC method. The model implemented priming by retrieving the memory encoding the peer-demonstrated method. Each retrieval increased the base-level activation of that memory according to Eq. (1). When the model began its post-intervention phase, since the method it observed during the intervention was the KIC method, the KIC method's memory had a relatively high base-level activation compared to that of the icon method. Therefore the memory encoding the KIC method then had a relatively higher likelihood of winning the retrieval competition than did the memory encoding the icon method.

### 4.2. Results and discussion

We used our model to simulate data from 1000 subjects to allow effects to converge well on the model's true predictions. As seen in Fig. 3, the mean efficiency rates, pre- and post-intervention, for the model's behavior mimics that of the experimental subjects', i.e., efficiency increased by 11%, from 43% to 54%, after observing someone use KICs. This indicates that the retrievals during the intervention phase increase the base-level activation of the KIC

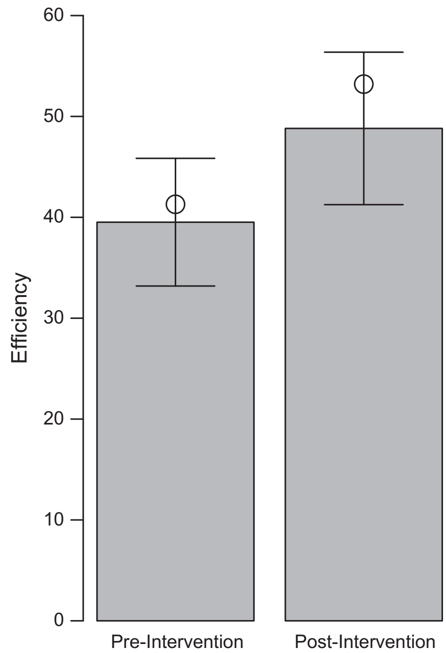


**Fig. 3.** Mean pre- and post-intervention efficiencies from the efficient condition (subject means, column) and the model (circles). Error bars depict the 95% confidence intervals of the human means.

method's memory such that by the end of the intervention phase the KIC method had a higher base-level activation than the icon method, and so it won the retrieval competition when the model began task performance in the post-intervention phase. We therefore claim that priming for KIC from observation of peers' actions is the cognitive mechanism underlying behavior change in a social learning context.

## 5. General discussion

We demonstrated in a novel empirical study that subjects will adopt efficient interaction methods under the condition that the subjects observe peers using those methods. Our ACT-R model explains in precise terms the mechanisms by which that occurs. The results of the computational cognitive model support our hypothesis that the mechanism behind peer-mediated method selection is a competitive activation retrieval process that is sensitive to priming provided by observation of peers' actions. To our knowledge this is the first study to establish a causal relationship between observation of peers and beneficial behavior change, and to elucidate a cognitive mechanism for the relationship.

Together the experiment and the model resolve the paradox of the active user and explain it as a combination of cognitive and environmental factors. For this domain, when users arrive at a part of a task in which multiple methods are available and one must be selected, there arises a selection competition akin to (Stroebe et al., 2013) theory of goal competition. Users must balance competing goals of accomplishing their task and learning how to do so more efficiently, and so they take the path of least resistance. That path is through the method most readily retrieved from memory. When the environment is one user alone with a computer, the path of least resistance tends to be the GUI methods as those are primed by the environment whereas the KIC methods are not, as Fu and Gray suggested (Fu & Gray, 2004).

However, given the social nature of normal, healthy individuals peers represent particularly salient environmental factors. Unlike computers, which tend to only prime objects such as the on-screen icon toolbar, peers can prime not only objects but also actions when users observe peers performing those actions. By being highly salient parts of a user's environment with the unique capability of priming actions, peers become particularly influential in the process of a user's competitive method selection process.

Expressing our theory of social learning by priming in terms of a computational model run as a simulation was beneficial for elucidating the interplay of dynamic mechanisms at work in our experiment's task environment. With a computational model we were able to claim not only that priming would result in KIC adoption, but we could specify how much priming would lead to how much KIC adoption. This specificity is important for theoretical accuracy since these quantities are part of what define the natural phenomena and it is important for future application development.

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